URBAN MODELING CAPABILITIES AT ENVIRONMENT CANADA

Sylvie Leroyer\textsuperscript{1}, Stéphane Bélair\textsuperscript{1}, Syed Husain\textsuperscript{1}, Simon Pellerin\textsuperscript{2}

1. Environmental Numerical Prediction Research (E-RPN), Meteorological Research Division, Science and Technology Branch, EC
2. Québec Region Lab, EC

Workshop on the SIMMER project, Toronto, 24 October 2013
Urban Modeling Capabilities at Environment Canada

◆ Research
  • Projects with Canadian Universities and observational network (EPiCC, MUSE)
  • International project TOMACS (Tokyo, Extreme Weather forecasting)

◆ Support to special events
  • PanAm / ParaPanAm 2015
  • Olympics Games Tokyo 2020 ?

◆ Numerical Weather Prediction (NWP)
  • Development of new systems for weather forecasting: Higher resolution + Urban effects

◆ End-users
  • project studies of mitigation strategies (QC)
2013
IOP

2014
Jan
200 m GEM-SURF National Experimental CMC

June
IOP

2015
May
250 m Integrated NWP system Toronto – VERSION 1

July-Aug
PA2015
250 m NWP Operational CMC
- Toronto
- Montreal
- Vancouver

Evaluation

Coupling with Lake and waves models NEMO (optional)

Real time forecasting

2016

Support to PanAm 2015
Timelines for urban NWP systems
Support to PanAm 2015: NWP Integrated System

2.5 km National CMC-Operations
4 runs / day

External Surface Modeling
GEM-SURF (200 m)

Canopy/soil physical processes
• TEB (urban)
• ISBA (vegetation), or SVS

Continuous cycle → daily surface forcing

Atmospheric System

Upper-air Ics and LBCs

Atmospheric forcing

Surface Initial conditions

Wall, Road, Roof: Ts
Soil: T, w, snow

Outputs & derived products:
• Outdoor thermal comfort indices: UTCI, WBGT, PHS (heat stress)
• High impact weather: heavy rain, strong wind
  • Fog / visibility

NEMO (lakes)
optional

urbanized GEM-LAM Cascade (real-time)
Support to PanAm 2015: NWP Integrated System

External Surface Modeling

GEM-SURF (200 m)

Canopy/soil physical processes
- TEB (urban)
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Continuous cycle → daily surface forcing

Low cost
The core of the Canadian Urban modeling system

Core:
TEB, Town. Energy Balance

Refs:
- Masson 2000, Masson et al. 2002,
- Lemonsu et al. 2004
- Leroyer et al. 2010

Shadowing effects and multiple radiation reflexions in the canyon
**Research:** urban GEM-Surf over Montreal

Leroye et al. (2011)

**Operationnall NWP model (Regional)**

First Atmospheric level

Meteorological Inputs interpolated on the refined grid

Surface atmospheric level (canopy top)

- Urban classes (from semi-automatic 60-m classification (*Lemonsu et al. 2006*)

- Forcings

- Downscaling of wind, Temperature, humidity, precipitation, solar and IR radiations

- Here, 120 m

- Here, 15 km

- Outputs:
  - Surface and near-surface variables
  - Turbulent fluxes, $T_s$ for different facets $T$, $q$, wind

- Surface schemes
  - TEB & ISBA

- Z=40 m

- Z=40 m
Canadian Operational Model
Product: Regional (North America)
Resolution: 15 km
Data assimilation every day, for:
- Soil temperature and water content (skin and deeper layer)

Radiative Surface Temperature (°C)
July 6th 2008 (11:00 LST)
Warm and Sunny

Urban GEM-Surface
Resolution: 120 m

Simulation Period:
May – September 2008
Run Timestep: 30 min
Forcing Timestep: 1 h

NWP versus this system
VERIFICATION AGAINST MODIS

**Urban off-line modeling system**
Resolution: 120 m

**MOD11A1 product**
Resolution: 1km (exactly 928 m)
- Atmospheric effects corrected
- Satellite View Angle: 15°

**Radiative Surface Temperature (°C)**
July 6th 2008 (10:54 LST)
Warm and Sunny

(Leroyer et al., 2011)
VERIFICATION AGAINST MODIS

Comparison with MODIS

MOD11A1 product
Resolution: 1km
(exactly 928 m)
- Atmospheric effects corrected
- Satellite View Angle: 15°

- Radiative Surface Temperature (°C)
  July 6th 2008 (10:54 LST)
  Warm and Sunny

Urban off-line modeling system
Resolution: 928 m
→ upscaling

(Leroyer et al., 2011)
Forecast of the Montreal Canopy Urban Heat Island

Nocturnal 2m Air Temperature (simulation, 120m)

6 July, 01:00 LST

max UHI : 5-6 °C
Generation of Country-wide Urban Input Parameters

Consistency and priorities, and spatial buffering

Look-up Table for each 5-m element (e.g. parking lot element, 100% road...)

<table>
<thead>
<tr>
<th>Classification</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land covers</td>
<td>$t_{veg}$, $t_{road}$, $t_{roof}$</td>
<td></td>
</tr>
<tr>
<td>Morphological parameters</td>
<td>$h_{blc}$, $W_{blc}$</td>
<td></td>
</tr>
<tr>
<td>Radiative parameters</td>
<td>$d_{roof}, d_{road}, d_{wall, i=1,2,3}$</td>
<td></td>
</tr>
<tr>
<td>(albedo, emissivity)</td>
<td>$\alpha_{roof}, \alpha_{road}, \alpha_{wall}$</td>
<td></td>
</tr>
<tr>
<td>Thermal parameters</td>
<td>$E_{roof}, E_{road}, E_{wall}$</td>
<td></td>
</tr>
<tr>
<td>(capacity, conductivity)</td>
<td>$\rho_{c,roof}, \rho_{c,road}, \rho_{c,wall, i=1,2,3}$</td>
<td></td>
</tr>
<tr>
<td>Anthropogenic heat fluxes (sensible and latent)</td>
<td>$Q_{H, traffic}, Q_{H, industry}$</td>
<td></td>
</tr>
<tr>
<td>Aerodynamic surface roughness</td>
<td>$z_{0,roof}, z_{0,road}$</td>
<td></td>
</tr>
</tbody>
</table>

Grid-scale parameters

- Wall to horizontal surface ratio: $F_{walls} = 2 \cdot h_{blc} / \rho_{c,roof}$
- Frontal aspect ratio: $\lambda_{f} = F_{walls} / 2$
- Canopy aerodynamic roughness: $z_{0,canopy}$ (Macdonald et al., 1998)
Generation of Country-wide Urban Input Parameters

Consistency and priorities, and spatial buffering

**Look-up Table for each 5-m element (e.g. parking lot element, 100% road...)**

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<th>Formula</th>
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<td>Land covers</td>
<td>$f_{veg} f_{road} f_{roof}$</td>
</tr>
<tr>
<td>Morphological parameters (building height, width, layers thickness)</td>
<td>$h_{bd}$ $W_{bd}$</td>
</tr>
<tr>
<td>Radiative parameters (albedo, emissivity)</td>
<td>$\alpha_{roof} \alpha_{road} \alpha_{wall}$</td>
</tr>
<tr>
<td>Thermal parameters (capacity, conductivity)</td>
<td>$\epsilon_{roof} \epsilon_{road} \epsilon_{wall}$</td>
</tr>
<tr>
<td>Anthropogenic heat fluxes (sensible and latent)</td>
<td>$Q_{H\text{traffic}}, Q_{E\text{traffic}}, Q_{H\text{industry}}, Q_{E\text{industry}}$</td>
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**Grid-scale parameters**

- Wall to horizontal surface ratio
  \[ F_{walls} = 2 h_{bd} f_{roof} / W_{bd} \]
- Frontal aspect ratio
  \[ \lambda_f = F_{walls} / 2 \]
- Canopy aerodynamic roughness
  \[ Z_{0\text{canopy}} = \text{(Macdonald et al., 1998)} \]
Toronto: GEM-LAM grid (1km)

Roads fraction

Street canyon depth
Support to PanAm 2015: NWP Integrated System

2.5 km National CMC-Operations
4 runs / day

Upper-air lcs and LBCs

Atmospheric System

1 km
554 x 554

250 m
824 x 824

urbanized GEM-LAM Cascade (real-time)

Waves

T5

External Surface Modeling

GEM-SURF (200 m)

Atmospheric forcing

Canopy/soil physical processes
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Surface Initial conditions

NEMO (lakes) optional
Support to PanAm 2015: NWP Integrated System

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urbanized GEM-LAM Cascade
Research: Coastal Urban Modeling with GEM-LAM

Leroyer et al. (2013), *in revision*

→ Sea-breeze event (14-15 Aug. 2008)
→ EPiCC IOP (Environment Prediction in Canadian Cities network)
→ Nested in RDPS
→ 33 hours studied
Evaluation of the Urban Thermal Forcing

Radiative Surface Temperature

Satellite view angle: -12 degrees. Time: 1100 LT

Influence of the model grid spacing + urban effects

<table>
<thead>
<tr>
<th>Statistics over urban pixels</th>
<th>Resolution</th>
<th>250 m</th>
<th>1 km</th>
<th>2.5 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>With Urban effects</td>
<td>STDE</td>
<td>2.6</td>
<td>3.0</td>
<td>3.4</td>
</tr>
<tr>
<td>No urban effects</td>
<td>STDE</td>
<td>3.6</td>
<td>3.4</td>
<td>4.3</td>
</tr>
</tbody>
</table>
Convergence zone over the suburban areas
Influence of the grid spacing in the model

Aug 14  1000 LT

2.5 km grid spacing

Potential Temperature

→ 5 m s⁻¹

Altitude ASL (m)

θ (K)

0 6400 m

Influence of the grid spacing in the model

Potential Temperature

→ 5 m s⁻¹

Altitude ASL (m)

θ (K)

0 6400 m

Convergence zone over the suburban areas
Convergence zone over the suburban areas
Influence of the grid spacing in the model

Aug 14  1000 LT

1 km grid spacing

Potential Temperature
Convergence zone over the suburban areas
Influence of the grid spacing in the model

Aug 14  1000 LT

250 m grid spacing

Potential Temperature
Evaluation of the Mixed Layer Height (Ceilometer)

- Morning deepening of the Mixed Layer height
- Drops observed – subsidence
Influence of the urban area on the Convergence Lines

(a) URB250 and VEG250 (1000 LT)

Importance of for
**Research**: Multi-Level Coupling (Urban Canopy)

- CaM-TEB (Canadian Multilayer version of TEB)

**Features**

- Several model levels intersect the buildings.
- Variable building heights exist within a grid cell.
- TEB is used for canopy surface temperatures assuming:
  - No differential heating.
  - All roofs in a grid cell have equal temperatures.

*(Husain et al. 2013)*
Improvement of the near-neutral layer forecasting with CaM-TEB in Oklahoma City (Joint Urban 2003)

Canadian Multilayer version of TEB, Husain et al 2013a, 2013b

Here, runs with 1 km grid spacing

Slope of temperature gradient
Developments: Heat Stress Indices in NWP systems

Main external factors influencing the human body

- Air temperature \textit{(ok)}
- Air humidity \textit{(ok)}
- Wind velocity \textit{(ok)}
- Radiations

\rightarrow \text{mean radiant temperature}

Radiative budget takes into account multiple reflections
Conclusions

• Numerical Runs going on over the region of Toronto

• Current optimizations and development of the Integrated system

• Case studies:
  • Extreme weather
  • 8 July 2013
    (... Very complex case: not only urban)

• Plan to run Heat Waves events
  (test of thermal indices)
Thanks for your attention!

Sylvie.leroyer@ec.gc.ca